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ABSTRACT

Two studies used a structural equation model to examine the relationship between gender and participation in college mathematics, physics, and chemistry courses. The intervening variables under scrutiny were ability scores, attitudes toward mathematics and mathematicians, and expectations of future performance in physical science courses. The paths which best explained the connection were (1) Sex/Ability/Expectations/Participation, and (2) Sex/Ability/Attitudes/ Expectations/Participation. In no case was gender a direct cause of participation, but in all cases explanatory paths involved variables influenced by the process of socialization. Thus, to increase women's participation, this model suggests that interventions oriented toward giving them more skills, creating more positive attitudes and creating higher expectations would all be effective. (Author)

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A Path Analytic Explanation of the Lower Participation Rates of Women in College Physical Science

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Males and females differ in the degree to which they participate in the physical sciences at all levels in the educational world; females are always underrepresented. Women comprise only about 4.8% of the tenure-track faculty in mathematics departments at institutions which grant a doctorate in mathematics, and the situation in other physical science areas is similar. One reason for this low percentage seems to be that few women receive Ph.D.'s in math. In fact, only 8% of the doctorates granted in mathematics from 1969-1975 were earned by women. Similarly, only 8% of the astronomy degrees were earned by women, 6% of the computer science degrees, 3% of the physics degrees, and 1% of the engineering degrees.

These low percentages are not restricted to the highest levels of educational attainment. From Lucy Sells' thesis (1975) on enrollments at the University of California at Berkeley, it is clear that women are underrepresented in the physical sciences throughout the college years. Women come to college less prepared in these areas than men, elect majors in the physical sciences less often, and apply to graduate schools more rarely. One outstanding statistic Sells reports is that only 8% of the female applicants to Berkeley in 1972 had taken four years of high school mathematics, whereas 57% of the male applicants had completed those years. The effect of this lack of preparation, of course, is to effectively exclude women from taking college courses and majoring in the physical sciences as well as from obtaining many lucrative jobs. Why do they cease taking mathematics so early in their lives?

One explanation of the low participation rates is a simple causal statement: if one is female, one does not participate in physical science. This is certainly much too simplistic, but it serves to introduce the structural equation model presented in Figure 1. The suggested explanation is represented by p_{51}, a direct causal path from Sex to Course Participation in

Physical Science. If the estimate of p_{51}, were high, one could conclude that the simple causal explanation had strong support. Simply being a woman would be sufficient cause to exclude one from the physical sciences.

However, a more realistic assessment of the relationship of Sex and Course Participation is provided through the model's inclusion of the intervening variables of ability in the physical sciences, attitudes toward the field, and expectations of one's performance in science-related situations. By including these variables in the model, the set of possible explanations has been expanded to include seven indirect paths from Sex to Course Election:

Sex → Ability → Course Participation

Sex → Attitude → Courses

Sex → Expectations → Courses

Sex → Ability → Attitude → Courses

Sex → Ability → Expectations → Courses

Sex → Attitude → Expectations → Courses

Sex → Ability → Attitude → Expectations → Courses

The purpose of the path model is to take the correlation between Sex and Course Participation and divide it into parts each of which identifies a path as accounting for a large or small part of the original relationship.

I will not go into detail on the literature in support of including these variables in a path model; suffice it to say that each general area is discussed at great length. Rather, let me attend to the model at hand and describe how each variable has been defined.

Sex. The variable of sex is equivalent to "male" in this model. This is not my personal preference, but it is a statistical preference. I wished to make the correlations between all variables positive, and being male is related to taking a large number of physical science courses in college.

Ability. Ability is a conglomerate variable, involving measures of aptitude as well as measures of achievement. In Study 1 it is a combination of three scores: the sum of the SAT math and verbal scores to represent general ability; the difference between the SAT math and verbal scores to provide an index of how much better a student is in math over verbal areas; and a difference score between high school physical science and humanities grades to supply an index of differential achievement. Standardized scores for each of these three variables were summed to arrive at the Ability variable in Figure 1.

In Study 2 the intent was to replicate and also to expand the model used in Study 1, and, thus, the Ability variable included a fourth score, that of Spatial Ability as measured by the Differential Aptitude Test Space Relations section.

Attitude. The Attitude variable in Study 1 may be called an anxiety measure since it included only one score, a measure of Humanities as opposed to Mathematics Anxiety. To form a score for this variable, the experimenter borrowed from Richard Svinn (1972) in asking students to rate how anxious they felt in about 200 school-related situations. Half of the questions talked about mathematics, e.g., preparing for a math test, having to add up a column of figures; while the other half asked about humanities, e.g., having to determine the structure of a poem, being assigned a difficult essay due the next class meeting. For each situation students rated the degree of their anxiety from "none at all" to "very much". Sums were made across all math situations and all humanities situations, and the Attitude score was computed by taking the difference between Humanities and Mathematics Anxiety scores. In this way, once again, a high score was related to a high level of participation in physical science.

This limited definition of Attitude was considerably expanded in Study 2 where three other variables were added to the difference in anxiety. First, Math as creative, a Torsted Husen (1967) measure of the degree of which students felt mathematics was a creative field and that one could be creative within it; second, Math as useful to know, another Husen measure; and third, Self-Image, a measure of how close one felt in self-image to a mathematician as opposed to a writer. Let me expand upon that last measure. Students were asked to use a series of semantic differential scales to describe a mathematician, then a writer, and lastly, themselves. The Self-Image score was a difference in the distance they placed Self from Writer, on the one hand, and the distance between Self and Mathematician, on the other hand. A high score thus means that one feels far away from a writer and very close to a mathematician. As with the Ability conglomerate, a total score on Attitude in Study 2 was the sum of the standardized scores for anxiety, math as creative, math as useful, and self-image.

Expectations. Expectations was yet another conglomerate including two measures: a difference between the grades one anticipated one would receive should one enroll in physical science as opposed to humanities courses; and a difference in the degree of liking one expected to have for a physical science course as opposed to one in the humanities. In both Studies 1 and 2, then, Liking and Expected Grades were standardized and summed for the conglomerate called Expectations.

Courses. Courses in Physical Sciences represented the degree of involvement of students in the Departments of Astronomy, Chemistry, Mathematics, and Physics for Study 1. In Study 2 the Department of Engineering was also included.

Seventy-five sophomores and juniors (with a sprinkling of seniors) from a small coeducational New England university supplied the data for Study 1. The

important correlation for the present analysis is that of Sex and Course Participation, and that correlation is .220, $p < .05$. It is this correlation which we will partial into paths to determine the strongest causal possibilities.

The first result of note is that the path coefficient between Sex and Course Participation, p_{51}, equals .055. The parentheses around that path coefficient indicate that that value is not statistically significant. That is, one cannot conclude that a student will or will not take courses in the physical sciences simply on the knowledge of that student's sex. We know that these two variables, Sex and Course Participation, are related or significantly correlated, but there is not a direct and significant causal path between them. To explain the relationship, we need to look at those indirect paths whose coefficients are significant.

Only two of the seven indirect paths lead successfully from Sex to Courses:

Sex → Ability → Expectations → Courses

Sex → Ability → Attitude → Expectations → Courses

The first of these paths can be described as follows: being female is related to receiving lower Ability scores; people with lower Ability scores have lower Expectations of their own performance in physical science; and people who have lower Expectations do not enroll in physical science courses. The other path is similar except that it adds the Attitude variable. So, in that second path, having lower Abilities in quantitative areas causes one to feel more anxious about quantitative subjects, and this anxiety leads to maintaining lower Expectations of one's own performance in quantitative fields.

A few comments on these paths are in order. One should note that the first step in each path is from Sex to Ability. This Ability cluster seems to be critical as a filter to women's participation in physical science. Women do relatively poorly on measures of quantitative ability--relative, that is, to men, as

well as to how well they do in measures of verbal ability. Why are women's quantitative scores so low? Elizabeth Fennema believes it is because they take fewer high school math courses than do men, and often elect high school courses at a lower level than men select. This sounds like we are entering a vicious circle. Women take fewer courses which means they learn less mathematics which leads to their receiving lower scores on quantitative tests which leads them to take still fewer courses. We certainly need to know more about the process of development of this cycle.

Another regularity of these two paths is the presence in each of the Expectations variable. It is the only variable which feeds directly into Course Participation. So, if one is trying to figure out why students enroll in various courses, this path would suggest that the answer lies in the grades students expect to receive and a more amorphous rating of the degree of liking they expect to feel for the course. That is quite a statement about motivation.

Because the sample size in Study 1 was small in path analytic terms, and because the contents of the cluster variables of Ability and Attitude were more restrictive than one might wish, Study 2 was conducted to replicate and expand Study 1. Seventy-nine students from a second small coeducational New England college were involved in this testing. To review, Ability in this second study contained the aptitude and achievement measures of Study 1 and added a measure of Spatial Relations skill. Attitude contained a similar anxiety measure to that in Study 1, and also measures of Math as Creative, Math as Useful, and Self-Image.

The lower diagram on Figure 1 shows the results of the path analysis in Study 2. There is remarkable agreement in the results. Again, there was a significant initial correlation between Sex and Course Participation, this time of

.233, $p < .05$, but the direct path between these two variables did not have a significant path coefficient, $p_{51}=.156$. Therefore, we have found additional support for the notion that knowing someone is female is not sufficient to explain her enrollment in physical science; consideration of the indirect causal paths is necessary.

To make a long story short, the same two indirect paths as were described in Study 1 are again the relevant causal explanations of the connection of Sex and Course Participation. Ability is a critical filter (to borrow a term from Lucy Sells) at the beginning of the path, and Expectations is critical at the end. With a second sample and more detailed variable definition, we find the same results as were defined for Study 1.

So, where have we arrived? We have a model supported by evidence to explain the low rates of participation of women in mathematics and physical science. Because of that model we may dismiss the direct causal explanation of the connection of Sex and Course Participation; the model has given us numbers to support the known fact that females are not by gender alone excluded from the sciences. Rather, to explain the low participation rates, one must appeal to a set of variables that are open to the vicissitudes of the socialization process. That is, we need to focus our attention on the variables of Ability, Attitude, and Expectations.

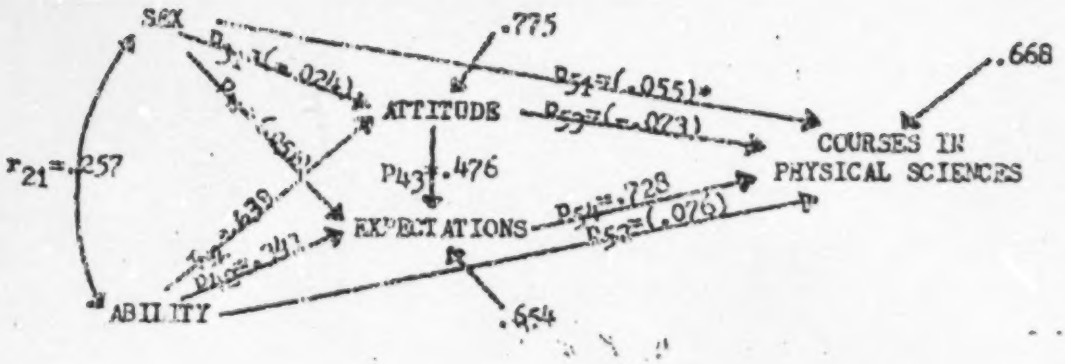
I have suggested earlier that developmental studies of these variables would be useful, particularly in the area of Ability differences between the sexes. I am not alone in this concern. Maccoby & Jacklin in 1974 stressed this area as one in which sex differences were regularly found. If Fennema is right that the Ability difference will disappear when samples are controlled for level of mathematical training, I should be interested to know that. But that information would only be a first step. There remains the question of why women have acquired less training.

Several practical suggestions emerge from this study for those people concerned with encouraging more women to explore their options in the physical science area. First, from the data on Ability comes the suggestion that parents, teachers, and guidance counselors should convince women to take mathematics courses in high school and in college. Even if taking more courses doesn't change the Ability difference between the sexes, it cannot help but improve the job options of women.

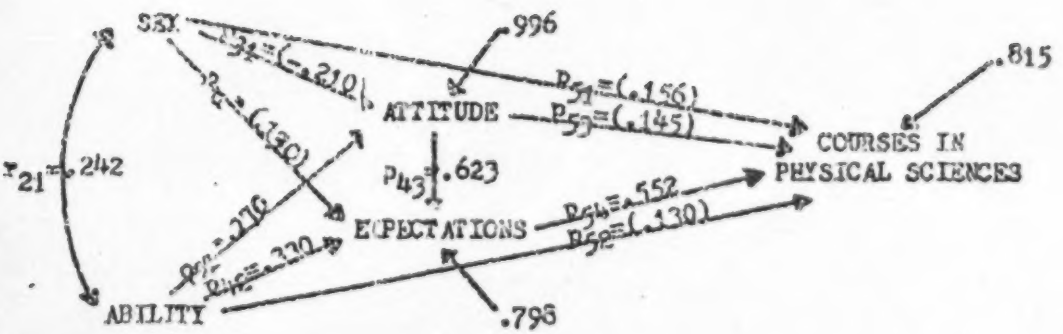
Second, we need to closely examine why so many students have very negative Attitudes toward mathematics. Why do so many express great anxiety in the fact of mathematical situations, why do many believe that mathematics is uncreative, that is, that all one does is memorize, not think; why do students believe that they will have no need of mathematical knowledge once they leave school; and why do they feel mathematicians are unsociable and purely rational people? The obvious explanation--that this is how mathematics and mathematicians are presented to them--cries out for revising mathematics curricula and teaching methods.

Lastly, we must look at those factors which influence student's Expectations about their performance in physical science courses. They claim that the grading is much tougher in these disciplines than in the humanities and social sciences. If this is true, are we prepared for its consequences?

We have here an effective explanatory model of women's lower rates of participation in the physical sciences; now let's see if we can't change the problem we've explained.



Coefficients for Sample 1
(N=75)



Coefficients for Sample 2
(N=79)

*Parentheses surrounding a path coefficient imply that the t-value associated with the coefficient is not statistically significant.